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Accuracy and Techniques in the Preparation of Mathematics Worksheets for Tactile Learners

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Abstract: Data were gathered from 166 participants regarding their qualifications for and training in preparing mathematics materials for tactile learners. The participants shared information about the courses and workshops they had attended, the books and resources they used, the amount of time they spent preparing mathematics materials, and information about the production of tactile graphics.

Mathematical competence is essential for independent living and gainful employment in adulthood. Individuals with a solid educational foundation in mathematics can solve problems for situations in daily life, successfully pass college entrance examinations, and obtain many of the most valued jobs in our highly technical society (Kapperman, Heinze, & Sticken, 2000). According to the National Council of Teachers of Mathematics (NCTM; n.d.), all students can learn mathematics if given high-quality instruction, challenging content, and appropriate accommodations, and well-prepared, knowledgeable teachers must have adequate resources and support to deliver high-quality instruction.

Mathematics relies on visual knowledge because visualizing abstract mathematical concepts allows individuals to understand both what is within sight and what is not within sight. The visual representation of mathematical problems offers individuals the ability to process many pieces of information simultaneously without the need for narrative and logical exposition (Arcavi, 2003). It also serves as a potential springboard for obtaining the solutions to more complex problems. Students with visual impairments (that is, those who are blind or have low vision) face challenges as they work toward mathematical competence, because the eye can more quickly and efficiently take in pieces of information simultaneously than can the fingers (Kamei-Hannan, 2009).

Students who are visually impaired may not understand the gestalt or whole picture

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of mathematical problems as quickly as sighted students, and helping them to understand all the parts of a picture or diagram can be time consuming for teachers. Diagrams may need to be broken down into logical and sequential parts for students with visual impairments to form complex mental images (Kapperman & Sticken, 2006). With direct instruction, high-quality tactile materials, and ample opportunities for practice, students who are visually impaired can develop these necessary skills and perform at grade level in mathematics. Accurate and well-prepared tactile materials, therefore, are an essential component for the success of students with visual impairments in mathematics.

A critical factor in the quality of braille production of mathematics materials is the quality of the training of the individuals who prepare them. Common types of training include university teacher preparation program courses, workshops, and conference sessions. When Amato (2002) polled 45 instructors from 34 teacher preparation programs in the United States, she found that only 22% thought that students who were completing their university-based braille courses would be capable of transcribing mathematics materials independently. She also noted a lack of consistency in the content of university-level braille courses. These programs reported different formats for instruction, different instructional materials and textbooks, different lengths and complexity of outside assignments, and different criteria that were used to determine minimum exit-level braille competence. Amato also reported that 20% of the 34 programs provided no instruction in the braille mathematics (Nemeth) code. Thus, a teacher who graduates from one of these universities may not have adequate skills to prepare high school–level mathematics materials in braille or be able to provide training to a paraeducator who is responsible for transcribing high school–level mathematics materials.

A perceived lack of or inadequate preservice training in the Nemeth code was also noted by Rosenblum and Amato (2004). In their survey of 128 teachers of students with visual impairments trained by 36 universities, Rosenblum and Amato found that only 28.9% reported that their university preparation in the Nemeth code had provided the information they needed to do their jobs. The teachers of students with visual impairments indicated that they most often prepared materials that involved basic operations, word problems, tactile graphics, and fractions. More than half the participants reported that they were currently responsible for transcribing algebra and geometry materials, even though some had not received any preservice training in the Nemeth code.

Although they did not directly study the quality of mathematics materials, DeMario and Lian (2000) surveyed 205 teachers of students with visual impairments from Illinois and Massachusetts about their perceived competence in the Nemeth code. The majority of respondents (78%) reported that they were currently serving students who read braille or students who would potentially read braille in the future. When these participants were asked about transcribing complex mathematics materials, their self-assessed anxiety ratings escalated. The majority reported that their competence in the Nemeth code was less than what was required for the transcription of materials for high school mathematics courses,

such as algebra and geometry. With limited structures for in-service training in the Nemeth code, coupled with inadequate or no preservice training, these increased anxiety ratings may be indicative of an awareness by personnel that they do not have the skills needed to transcribe mathematics materials correctly.

Teachers of students with visual impairments and the students they teach also need adequate support from paraeducators and transcribers (Rosenblum & Amato, 2004). There is a shortage of transcribers across the United States, and this shortage is expected to continue (American Foundation for the Blind, n.d.; Corn & Wall, 2002). In addition, a low percentage of available transcribers are certified to prepare Nemeth code materials through the Library of Congress, National Library Service for the Blind and Physically Handicapped (NLS).

Although there is a shortage of other professionals, a growing number of paraeducators are working with children with visual impairments in both itinerant and residential settings (Forster & Holbrook, 2005; Griffin-Shirley & Matlock, 2004; McKenzie & Lewis, 2008). Some of these paraeducators are responsible for preparing braille and tactile graphics that are used by students who read braille. Griffin-Shirley and Matlock (2004) found that 13 of 97 (14%) paraeducators prepared braille materials. This was a much lower number than what McKenzie and Lewis (2008) reported. McKenzie and Lewis found that approximately 68% of 107 paraeducators prepared braille materials, about one-fourth of the paraeducators reported they provided direct instruction in mathematics to students, and 61% reported that they provided instructional support. There is a need to ensure that paraeducators who prepare braille materials or carry out instructional responsibilities or both have appropriate training in the skills needed to prepare braille and tactile graphics accurately (Forster & Holbrook, 2005; Lewis & McKenzie, 2010; McKenzie & Lewis, 2008).

This article reports data from a larger study that examined the accuracy and techniques in preparing mathematics worksheets for tactile learners. The following research questions were investigated in the larger study:

1. Who prepares mathematics materials for learners who use braille, and what are their qualifications, including certification?
2. How are mathematics materials prepared for learners who use braille?
3. What is the perceived quality of the mathematics materials being prepared for learners who use braille?

A future article will report the results for the second and third research questions. This article reports on the background, training, and qualifications of individuals who are responsible for transcribing mathematics materials for students who are tactile learners.

Method

Instrument

An online survey was developed using Survey Monkey. The survey began with a brief description of the purpose of the study and contained 34 items divided into seven sections. Items asked about the participant's background, training, and skills in reading and writing the Nemeth code, as well as the participant's level of experience

in preparing tactile graphics. Additional items asked about the number of students who were supported, future training needs, and how the participants typically prepare mathematics materials in braille.

Before the study began, we asked several professionals (including teachers of students with visual impairments, transcribers, and university professors) to review the instrument to provide feedback on the clarity and order of the questions. Three individuals who used screen-reading software also reviewed the online survey and provided input about its accessibility and ease of use for those who used assistive technology.

Criteria for Participation and Recruitment

Approval to conduct the research was obtained from the Institutional Review Board at the University of South Carolina Upstate. The study was open to individuals who were currently preparing or had prepared within the past three years mathematics materials using the Nemeth braille code for tactile learners from preschool through Grade 12. Announcements of the survey were sent on electronic bulletin boards in the field of visual impairment and to graduates who had completed their preparation as teachers of students with visual impairments at the universities where we were employed.

Results

Demographic Characteristics of the Participants

Data were collected from February to May 2010. A total of 166 individuals participated in the first part of the study. The participants were initially asked to identify their job titles and could check as many titles as were applicable. We did not distinguish between or define the terms *braillist* and *transcriber.* Job titles for the participants varied and were multiple, so that the number of participants who reported various job titles exceeded the number of participants. Of the 166 participants, 80 were teachers of students with visual impairments, 11 were orientation and mobility specialists, 62 were braillists, 53 were transcribers, 40 were teachers' aides or paraeducators, and 1 was an administrator. Of the 80 who reported they were teachers of students with visual impairments, 16 also identified themselves as braillists or transcribers. Of the 40 who said they were paraeducators, 23 reported they were also either braillists or transcribers. The others ($n = 17$) did not indicate any additional roles. For the purposes of analysis, the participants were grouped on the basis of their roles: teachers of students with visual impairments ($n = 80$), transcribers and paraeducators ($n = 23$), transcribers and braillists ($n = 46$) and paraeducators ($n = 17$). Demographic data for the participants by role group are reported in Table 1.

Forty-four of the participants were certified by NLS in literary braille, 13 were certified in the Nemeth code, 1 was certified in music braille, and 2 were certified in the transcription of textbooks. Of the 80 who reported they were teachers of students with visual impairments, only 5 (6.3%) were NLS certified in the literary braille code and 1 (1.3%) was certified in the Nemeth code. Of the 69 who indicated they were braillists and transcribers, 38 (55.1%) were certified by NLS in literary braille and 12 (17.4%) were certified in the Nemeth code. Two additional participants indicated they were certified in literary braille through the

Table 1
Demographic characteristics of the participants ($N = 166$).

Characteristic	Teachers of students with visual impairments ($n = 80$)	Transcribers and paraeducators ($n = 23$)	Transcribers ($n = 46$)	Paraeducators ($n = 17$)
Gender				
Female	76	23	44	17
Male	4	0	2	0
Highest level of education				
High school diploma or GED	0	3	11	2
Some college	0	12	12	4
Associate's degree	0	3	8	3
Bachelor's degree	15	5	12	8
Master's degree	62	0	3	0
Doctoral degree	3	0	0	0
Years of preparing mathematics materials for tactile learners				
1–3	22	5	6	4
4–6	16	7	10	6
7–10	8	8	11	4
11–15	11	2	8	0
16 or more years	23	1	11	3

National Competency of Literary Braille Test. In general, the teachers of students with visual impairments reported that they spent less time each week transcribing than did the transcribers, braillists, and paraeducators (see Table 2).

All 166 participants reported that they could read and write numbers and simple, linear mathematics problems. Similarly, 163 (98.2%) of the 165 who answered the question indicated they could read and write mathematics problems in spatial formats, and 158 of the 166 (95.2%) could read and write fractions. Of the 164 who answered the question, 144 (86.7%) reported they could read and write algebra problems without exponents, and 137 (82.5%) of the 165 who answered the question reported they could read and write algebra problems with exponents. Finally, 114 (68.7%) of the 161 who answered the question indicated they could read and write geometry problems.

The data for algebra and geometry were examined by role group. Sixty-nine (87.3%) of the 80 teachers of students with visual impairments, 17 (73.9%) of the 23 transcribers and paraeducators, 44 (97.8%) of the 46 transcribers and braillists, and 14 (82.4%) of the 17 paraeducators indicated they could read and write algebra problems without exponents. For algebra with exponents, 65 (82.3%) of the 80 teachers of students with visual impairments, 15 (65.2%) of the 23 transcribers and paraeducators, 45 (97.8%) of the 46 transcribers and braillists, and 12 (70.6%) of the 17 paraeducators reported they could perform this skill. Moreover, 51 (67.1%) of the 80 teachers of students with visual impairments, 12 (52.2%) of the 23 transcribers and paraeducators, 42

Table 2
Types of training and number of hours spent each week transcribing.

Types of training and hours spent transcribing	Teachers of students with visual impairments (*n* = 80)	Transcribers and paraeducators (*n* = 23)	Transcribers (*n* = 46)	Paraeducators (*n* = 17)
Types of training				
Nemeth code				
One university course	46	0	2	0
Two or more university courses	6	0	0	0
Correspondence course	2	4	14	2
Attended workshop(s)	19	11	24	4
Attended conference session(s)	21	8	26	0
On-the-job training	23	11	27	9
Other	24	6	22	5
Preparing tactile graphics				
University course	21	0	1	0
Attended workshop(s)	34	12	29	4
Attended conference session(s)	27	8	21	0
On-the-job training	25	8	25	8
Other	17	6	10	6
Hours spent transcribing				
Literary braille materials				
1–5 hours per week	29	3	5	2
6–10 hours per week	15	2	4	1
11–15 hours per week	9	1	4	2
16–20 hours per week	4	7	7	6
21–25 hours per week	0	1	4	3
26 or more hours per week	1	4	11	0
Time requirements vary considerably from week to week	20	4	11	3
No response	2	1	0	0
Mathematics and science braille materials				
1–5 hours per week	33	3	3	3
6–10 hours per week	21	7	4	4
11–15 hours per week	2	3	5	3
16–20 hours per week	2	3	6	3
21–25 hours per week	3	1	2	0
26 or more hours per week	0	0	9	1
Time requirements vary considerably from week to week	17	6	17	3
No response	2	0	0	0

(93.3%) of the 45 transcribers and braillists, and 9 (52.9%) of the 17 paraeducators indicated they could read and write geometry problems.

Participants' training

The participants were then asked which statement best described the training they received in preparing mathematics and

science materials for tactile learners. Six (3.6%)—5 teachers of students with visual impairments and 1 transcriber or paraeducator—selected "It provided me with all the information that I needed to do my job." In addition, 21 (12.7%)—17 teachers of students with visual impairments and 4 transcribers or braillists—chose "There were some gaps in my training that I had to fill in once I began my job." Thirty-five (21.1%)—24 teachers of students with visual impairments, 3 transcribers and paraeducators, 6 transcribers and braillists, and 2 paraeducators—selected "There were many gaps in my training that I had to fill in once I began my job." Also, 89 (53.6%)—32 teachers of students with visual impairments, 14 transcribers and paraeducators, 32 transcribers and braillists, and 11 paraeducators—chose "I learned most of what I needed to know while on the job." Fifteen respondents (9.0%)—2 teachers of students with visual impairments, 5 transcribers and paraeducators, 4 transcribers and braillists, and 4 paraeducators—indicated they did not receive any training.

Types of training

From a list of common training methods that was provided in the survey (see Table 2), the participants were asked to select as many items as were applicable to them. Forty-eight participants (28.9%) had completed a course in the Nemeth braille code at a university, 6 (3.6%) had completed two or more university courses in the Nemeth code, and 22 (13.3%) had completed a correspondence course in the Nemeth code. In addition, 58 (34.9%) had attended workshops that focused on the Nemeth code, and 55 (33.1%) had attended sessions at conferences that focused on the Nemeth code. Slightly more than 42% (n = 70) had received on-the-job training. Also, 109 (65.3%) participants reported other ways in which they had received training. Of particular interest, 25 participants indicated they had taught themselves or learned on their own. Other responses included "learned by doing," "improved with "practice," "mentored by a skilled professional, "learned by studying examples in a textbook for students," and "learned from written materials and books."

A similar series of statements was provided about the training the participants had received in preparing tactile graphics (see Table 2). Once again, the participants could select as many as were applicable. Twenty-two (13.3%) completed a course through a university, 79 (47.6%) had attended workshops that focused on the production of tactile graphics, and 56 (33.7%) had attended conference sessions on the topic. Furthermore, 66 (39.8%) reported receiving on-the-job training, and 127 (76.5%) shared additional ways in which they were prepared, including 19 who had taught themselves. Other open-ended responses included "learned by doing," "mentored by a skilled professional," "learned by studying examples," "trial and error," "learned by reading professional books and articles," and "improved via feedback from students."

Support to students

When asked how often they supported students in the classroom, 45 (56.3%) of the 80 teachers of students with visual impairments said almost always, 16 (20.0%) said often, 12 (15.0%) said sometimes, 5 (6.3%) said on rare occasions and 2 (2.5%) said never. Similarly, 10 (58.8%) of the 17 paraeducators

reported providing support almost always, 3 (17.6%) said often, 2 (11.8%) said sometimes, and 2 (11.8%) said on rare occasions. The transcribers and braillists were less likely to support students in the classroom. Of the 46 transcribers and braillists, 6 (13.0%) replied that they almost always provided support, 5 (10.9%) replied that they often provided support, 7 (15.2%) replied that they sometimes provided support, 10 (21.7%) replied that they rarely provided support, and 18 (39.1%) replied that they never provided support.

Preparation of materials

The amount of lead time the participants were given to prepare materials varied (see Table 2). Of the 163 who responded, 16 (9.6%) were most often given the materials the same day they were needed, 58 (34.9%) were most often given materials 1–2 days ahead of time, 27 (16.3%) received materials 3–5 days ahead of time, and 12 (7.2%) were most often given a week or more to prepare the materials. The amount of time given to prepare materials was so variable for 50 (30.1%) participants that they did not select one of the previous four categories.

The participants were asked how often they consulted resources when preparing materials using the Nemeth code. Of the 165 who responded, 37 (22.3%) almost always consulted resources, 60 (36.1%) often consulted resources, 57 (34.3%) sometimes consulted resources, and 11 (6.6 %) consulted resources on rare occasions or never. These percentages were consistent across the role groups. The most commonly used resource (cited by 98) was the four-page *Nemeth Code Reference Sheet for Basic Mathematics* (American Printing House for the Blind, n.d.). In addition, *An Introduction to Braille Mathematics* (Roberts, Krebs, & Taffet, 1978) was consulted by 66, *Braille Formats: Principles of Print to Braille Transcription* (Braille Authority of North America, 1997) was consulted by 49, *Braille Handbook for the Nemeth Code of Braille Mathematics and Scientific Notation* (Laudenslager, 1972) was consulted by 79, and *Learning the Nemeth Braille Code: A Manual for Teachers and Students* (Craig, 1997) was consulted by 58. Other resources were less often used by the participants. *Braille Codes and Calculations* (Pesavento, 1993) was consulted by 14, *Strategies for Developing Mathematics Skills in Students who Use Braille* (Kapperman, Heinze, & Sticken, 1997) was consulted by 8, and *New Programmed Instruction in Braille* (Ashcroft, Sanford, & Koenig, 2001) was consulted by 7.

The participants were then asked how often they proofread their work; 135 (81.3%) reported they almost always proofread, 20 (12.0%) reported that they often proofread, 5 (3.0%) reported that they sometimes proofread, 5 (3.0%) reported that they proofread on rare occasions, and 1 (.6%) did not respond to the question. When asked why they did not proofread their materials, 28 reported either the lack of time or insufficient lead time. Of the 163 who answered the question, only 14 (8.4%) almost always had someone else proofread their materials, while 10 (6.0%) often, 24 (14.5%) sometimes, 43 (25.9%) on rare occasions, and 72 (43.4%) never had someone proofread materials.

The participants were asked how often they felt they needed additional information or support when transcribing mathematics

Table 3
Perceived quality of materials produced by respondents.

Quality	Teachers of students with visual impairments (n = 80)	Transcribers and paraeducators (n = 23)	Transcribers (n = 46)	Paraeducators (n = 17)
Excellent	11	3	14	2
Good	52	17	28	12
Fair	12	3	3	3
Poor	2	0	0	0
No response	3	0	1	0

materials. Of the 163 who answered the question, 13 (7.8%) said they almost always needed additional information or support, 33 (19.9%) said they often did, 84 (50.6%) said they sometimes did, 29 (17.5%) said they rarely did, and 4 (2.4%) said they never needed additional information or support. Furthermore, almost two-thirds of the participants thought that they would benefit from more training in the Nemeth braille code (n = 102; 61.4%) and in creating tactile graphics (n = 108; 65.1%). Other training needs were for literary braille (n = 22; 13.3%), the braille music code (n = 42; 25.3%), formatting in braille (n = 82; 49.4%), the use of technology to transcribe braille (n = 67; 40.4%), teaching the braille code to others (n = 27; 16.3%), assisting individuals to develop tactile skills for reading (n = 35; 21.1%), and assessing braille skills (n = 25; 15.1%).

Perceived quality of transcribed materials

The participants rated the quality of the brailled science and mathematics materials they produced. Of the 162 who answered the question, 83.8% (n = 139) rated the quality of the materials they produced as being either excellent or good, almost 13% (n = 21) rated the quality of the their materials as fair, and only 1% (n = 2) rated the quality of the their materials as poor. The responses varied somewhat by job-role groups (see Table 3). For the 44 participants who were certified by NLS, 15 (34.1%) reported that their materials were excellent, 27 (61.4%) them as good, 1 (2.3%) reported them as fair, none reported them as poor, and 1 (2.3%) did not respond to the question.

Discussion

This article has reported demographic data for 166 individuals who are responsible for preparing mathematics materials for tactile learners. The participants had various backgrounds and roles, which is similar to the findings of other authors (Allman & Lewis, 1996; Corn & Wall, 2002; Herzberg & Stough, 2007, 2009; Rosenblum & Amato, 2004; Wall & Corn, 2002). It was not surprising to find that the amount of lead time the participants were given to prepare mathematics materials for tactile learners was usually two or fewer days. General education teachers often do not plan ahead by more than a few days, so the lead time for those who prepare materials in braille is lessened. Often as a result of a short turn-around time, those who

prepare materials do not proofread them for accuracy.

Although the majority of the teachers of students with visual impairments had some preparation in how to produce mathematics materials for tactile learners, many still reported they had learned on their own through handouts, conference sessions, and other methods. As one teacher aptly stated, "It seems that you can never get enough instruction in braille; as the student grows, the needs grow, so it is a constant refinement of skills. I find it an enjoyable challenge to provide my student with his curriculum tactilely." Similarly, transcribers and paraeducators also reported learning on their own. The need for systematic ways for individuals to gain knowledge and skills, both in the Nemeth code and in the production of tactile graphics, is evident from these data and is consistent with what other researchers have found (Griffin-Shirley & Matlock, 2004; McKenzie & Lewis, 2008). As one participant wrote,

> As the only transcriber in a small rural county, I am a bit isolated and not connected with any group to get feedback and support from. Online training courses are very valuable to me and much appreciated to help me provide the best product I can for my students.

To assist this individual and others, self-paced online learning modules and live workshops should be developed that can facilitate the learning of essential skills needed to produce accurate mathematics materials for tactile learners. The use of online conferencing tools is a viable option for delivering such content in a live format without the cost of travel for participants.

More transcribers than teachers of students with visual impairments and paraeducators reported that they could read and write advanced mathematics problems. Although the vast majority of participants believed that the materials they prepared were excellent or good, 14% believed that the quality of the materials they produced was fair or poor. From our initial analysis of data to be reported in a subsequent article, we question some of the self-ratings based on the quality and accuracy of the materials the participants submitted. Students with visual impairments have lower achievement in mathematics relative to students without visual impairments, as well as reduced participation in the science, technology, engineering, and mathematics (STEM) fields (Cavenaugh, 2006; National Science Foundation, 2009). It is possible that materials that are not accurately prepared may play a part in the lower achievement scores and representation of students with visual impairments in STEM fields. Comments such as this one from a teacher of students with visual impairments, prompt one to wonder: "I'm not sure if I'm correct, but I feel that my student needs the materials, even if there are errors, more than he needs a perfect worksheet." Future research on the impact of the quality of brailled materials on the success of students in mathematics should be conducted.

Limitations

The study was not without limitations. The data were self-reported and were not verified by us or corroborated by the participants' supervisors. In addition, although most participants reported they

could read and write the Nemeth code, on the basis of an initial analysis of their hard-copy braille transcriptions, we doubt the accuracy of the self-ratings in some cases. Another limitation was that the participants were not asked to indicate what state they were from. In the second part of the study, which will be reported in a future article, the participants mailed hard-copy braille to the second author, who observed postmarks from approximately 35 states. Thus, a wide geographic representation can be deduced, but data are not available to report. An additional limitation was the lack of data on the size of caseloads. Probably the greatest limitation was that the terms *transcriber* and *braillist* were not defined when the participants were asked to identify their roles. Therefore, some individuals who were certified braille transcribers checked braillist, and some individuals who were not certified braille transcribers checked transcriber. Although this is a limitation, it is clear from the data that some teachers of students with visual impairments are also certified braille transcribers. A surprising finding is that some individuals who indicated they were only braillists or transcribers spent time in the classroom supporting tactile learners.

We were surprised by the large number of individuals who completed this survey. This finding may be indicative of the need of many to share and learn with regard to the Nemeth code and the production of tactile graphics. A transcriber commented,

> I feel my graphics on the worksheets that I do are not the quality that the students deserve. Given more time to prepare them, and if I had been given the necessary training, as well as the equipment to produce graphs and images, then I feel I could give the students better quality. I basically learned as the students learned and used many resources. I did so because otherwise the students would not have been able to excel to the point that they have.

In the field of visual impairments, training solutions should be actively sought so that all individuals with the responsibility of preparing materials for tactile learners are trained and have the necessary skills and tools to prepare accurate and high-quality materials. All students deserve this basic right.

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